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*A Musculoskeletal Model-based Evaluation and Validation Study*

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# Compensatory Movements Involved During Simulated Upper Limb Prosthetic Usage: A Musculoskeletal Model-based Evaluation and Validation Study

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## Introduction

Prosthetic arms have generally seen poor outcomes as the perceived functional gain is limited by the disadvantages [1]-[2]. Most upper limb (UL) prostheses, especially affordable prostheses, lack controllable distal joint(s) which necessitates compensatory movements at the proximal joint(s) during functional use [3], and these movements are linked to prosthesis rejection [4]. Studies characterising such movements are mostly limited to kinematic analyses [3],[5]-[7] and few studies have adopted a multi-body musculoskeletal (MS) model-based approach in this field. MS models facilitate estimation of *in vivo* loading and enable 'what-if' analyses; although, it should be noted that MS model Verification & Validation is a non-trivial endeavour and remains a vital topic of ongoing research [8]-[10]. Hence, the objective of this study is to perform (i) MS model validation and (ii) MS model-based evaluation of the compensatory movements adopted during simulated prosthesis usage.

## Methods

This study was approved by the local Research Ethics Committee (Ref no. 16/SC/0051). Eleven adult able-bodied participants consented to participate in this study. Three trials of a *Reach-to-grasp* task in a 3D marker-based optical motion capture laboratory setting were performed in a seated position using a custom-built apparatus. Surface EMG (sEMG) data pertinent to maximum voluntary contractions of select muscle groups were recorded for model validation purposes. Movement data and sEMG data were collected during task execution. Prosthesis usage in the participants was simulated using a commercially-available wrist brace that mimics lack of a controllable wrist in a typical prosthetic arm. The *Standard MoCap* model in the AnyBody Managed Model Repository v.1.6.5 distributed with the AnyBody Modelling System™ was used to estimate *in vivo* loading. Study validation was performed by indirect, qualitative, and quantitative comparison [11].

## Results and Discussion

Study validation reveals that the magnitudes of shoulder joint loading were generally in agreement with those reported in relevant published studies [12]-[13]. For qualitative comparison, the shapes of calculated and recorded muscle activity curves matched well. In general, joint loading values were lower for the braced condition. Trends such as smaller joint reaction forces at the shoulder and higher joint moments for the trunk and elbow were seen for the braced condition.

## Conclusion

The first-ever study involving MS model-based characterisation of compensatory movements adopted during simulated prosthesis use and model validation has been carried out. This study is expected to improve the objectivity in measuring prosthetic function and personalising device.

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